Berlin, 22 Feb 1944

Problems of Measurement in the Development of Anti-Aircraft Rockets

I. Trajectory measurements involve the following determinations:

initial trajectories of starting anti-aircraft rockets; all phenomena immediately after starting and during the jettisoning of assisting takeoff devices; behavior of the controls; flight performance of a missle passing through the sonic barrier; flight performance at the point of combustion cutoff; deviation of the trajectory from the theoretical flight path; range; sensitivity of the fuzes; and precision with which the trajectory can be measured by kinetheodolites.

II. The control of AA rockets along a pre-determined flight path requires the following devices:

(1) one target path device or program device;

(2) one kinetheodolite, remote-controlled by the target path device;

(3) two kinetheodolites for tracking.

Method of operation:

Kinetheodolite (2) is remote-controlled according to the program by the target path device. Its cross-hairs center thus represents the target. The path deviations of the controlled AA rockets can be determined from the kinetheodolite pictures by azimuth and elevation, but not by range. The trajectory is determined from the pictures of the two kinetheodolites (3). All kinetheodolites are synchronized.

III. Data describing the flight performance are to be transmitted to the launching site by radiosondes from the rocket in flight. This data is: combustion chamber pressure, velocity of exhaust jet, decrease in feed pressure, temperatures, positions of control surfaces, etc.

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The requirements for radiosondes are as follows:

1) the "Rheintochter" rocket should measure three data simultaneously.

2) the "Schmetterling" rocket should measure five data in quick succession. its dimensions: Maximum 9 x 13.5 x 28 cm, and weight: maximum 20 kg.

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Berlin, 20 Sept 1944

Conference on the "Taifun" Rocket, 14 Sep 1944

Technical data:

Caliber: 10 cm, with stabilizer wings.

Length : 1.90 m.

Weight without warhead: 7 kg.

Weight of warhead with fuze and explosive charge: 2 kg.

Effective propulsive charge: 10.2 kg.

Combustion time: 4 sec.

Ballistic efficiency: With a weight of 9 kg plus 10 kg of fuel, and vertical launching, a speed of 1264 m/sec is reached at the point of combustion cut-off at an altitude of 2.4 km altitude. An altitude of 10 km is reached after 12.6 sec at a speed of 906 m/sec. Since the drag between Mach numbers 1 and 3 is higher than stated in the drag function used for the calculations, 10 km altitude will probably be reached only after approximately 15 seconds. The angle of attack must be 0°.

Propulsion: The propulsion unit consists of a 1-mm thick steel tube containing fuel. Its interior holds a 2-mm thick aluminum tube containing nitric acid. Both sides are closed off by bursting diaphragms. At the head end is a gas-generating cartridge. When cartridge is set off and the gas pressure reaches approximately 12 atm above normal, the diaphragms burst. The rear end contains the nozzles and antechamber and the combustion chamber and exhaust nozzle, with the control surfaces arranged around it. At full combustion, the combustion chamber is 40 atm above normal and the liquid tanks are 60 atm above normal. Combustion time is 4 sec. This time cannot be shortened, since throughput is limited by the ratio between nozzle cross-section and caliber. Propulsion units with less fuel operated on the test stand. Flight tests have also been carried out. The gas cartridge must be

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further developed for more rapid increase in gas pressure after initial set-off. Although the nozzle plates seem uniform, thrust fluctuates. It is still not known down to which launching angle the liquid will be pressed properly into the nozzle.

Ignition is electrical; one lead is grounded and the other one runs through an insulated toggle switch. The location of leads on the warhead has not yet been determined.

Fuzes: At present only AZ 5095/1 fuzes are being manufactured, for use in "Panzerschreck" anti-tank rockets. These do not have the necessary safety required for use in "Taifun" rockets.

The missile is to be exploded by a delay train set off upon ignition of the cartridge. A safety element must be installed to ensure the explosive charge's being set off only after launching.

Launchers: The Skoda Works design was submitted. It provides for the rebuilding of the mount of the 8.8 cm Flak 36 gun. Barrel and counterrecoil mechanism are dismantled. In their place, 46 rocket launcher tubes are installed. Originally the length was to be 2 to 3 m, but will probably have to be increased to 5 m. Gunners will be shielded by walls 6 to 8 mm thick. It is not yet known how many missiles can be launched simultaneously, or how long the intervals between launching of individual missiles have to be to prevent them from interfering with each other. It is not yet known whether the missiles have to be anchored with pins.

Fire control unit: Since the missile is designed to attack bomber formations and is fitted with percussion fuze, the fire control unit can be simple. The "Malsi" anti-aircraft converter seems suitable, since its range can be set at will. Whether its accuracy can be made to match the scatter of the rockets is still unknown. The "Kommandogeraet 36" anti-aircraft director might also be used. Eight to ten launching sites can be connected to it.

Each battery is to be equipped with at least six launching racks, to eliminate the firing pauses caused by the reloading of the rack, which takes about four minutes.

Berlin, 14 Oct

State of Development and Problems of Project "Taifun"

Ballistics and aerodynamics: Trajectories were calculated for [elevation] ~~phi~~-angle φ = 90°, 80°, ~~and~~ 45°, assuming a total weight of 20 kg plus propulsive charge of 10 kg and 2000 kg thrust. The angle of attack alpha was assumed to be zero.

At φ = 90° and φ = 80°, an oblique distance of 10.35 km is reached in 15 sec. The oblique distance at φ = 45° is 10.0 km. Reducing the total weight by 1 kg while maintaining the weight of the propulsive charge one increases the altitude for vertical firing from 10.35 km within 15 sec to 10.7 km, or a reduction in flight time to reach an altitude of 10 km from 14.3 sec to 13.5 sec. It has not yet been determined whether the theoretical drag coefficients match the actual ones.

Stabilizing: ~~control~~-surface diameter is 240 mm and the length is combustion chamber plus nozzle (282 mm), so that the control surfaces do not extend beyond the body; tests will probably show that the diameter can be reduced further.

Aerodynamic calculations: To be determined are tumbling frequency, expected angle of attack and subsequent increase in drag coefficient effect of propulsion upon drag, buckling moment on missile jacket due to air forces and inertia.

Launching: To obtain proper guiding of the missile in the launching trough, two guide bulges are to be attached to the front and rear end of the jacket to compensate for the bending of the external tanks, which is unavoidable during manufacture. It is estimated that flight time will be increased thereby by 3 to 4%. The length of the launching trough is to be 3.50 to 4 m.

Spin: a slight spin about the longitudinal axis, effected by setting

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the control surfaces at a slight angle, is provided for to compensate for any non-asymmetry in construction or moment of rotation caused by the direction of thrust. The spin frequency which can be employed without giving rise to tumbling motions has not yet been determined. It is also to be attempted to increase the still inadequate stability by rifling the launcher and imparting an initial spin to the missile.

Propulsion: High thrust and short combustion time to reduce scatter; test stand runs show that a 700-kg thrust and a 3-sec combustion time can be attained.

Generation of compressed gas: The chief difficulty here lies in the unsatisfactory performance of the cartridge which supplies the compressed gas for the fuel feed. The powder train pressed into the steel cylinder presently in use develops too high a temperature (1000 to 1100°C), thus causing the perforated plate and jacket top to glow or burn through. Besides, slag is formed which plugs the nozzles. A new gas cartridge using diglycol or similar powder is to be developed.

Handling: Contact between nitric acid and fuel and subsequent combustion can occur from either concussion or enemy fire. Final assembly must therefore be carried out, at least partially, at the launching site. The fuel can be filled at the site, while the nitric acid may be filled at the manufacturing plant.

Warhead difficulties still to be overcome involve the designing of a warhead and launcher rack that provide for supply-voltage leads to the gas cartridge for setting it off. An induction cartridge release mechanism is being worked out.

The pyrotechnic self-destroyer tube has functioned on the test stand at low pressures, but ignition and connection with the powder train are still difficult. Designing of a mechanical self-destroyer fuze may solve this problem.

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Fuze: the present fuze is armed after completion of combustion; i.e. after a flight path of about 2km. By a slight modification the fuze can be armed an instant, 0.1 sec, after the missile has reached a certain acceleration (i.e. at any point of the trajectory prior to the combustion cut-off point) by varying the strength of the spring.

The acceleration in the launcher, and immediately afterwards, is to be determined by a telescopic-lens camera with 50 exposures per second (camera simultaneously photographing a stopwatch).

From a sufficiently great lateral angle, this camera can also be used to photograph the oscillating motion of the missile.

Slow-motion movies of the exhaust flame on the test stand are to be taken to obtain information on thrust development.

The trajectory is to be measured with phototheodolites, with the aid of one or more illuminating charges.

Berlin, 14 Oct 1944

Computation of Trajectory for Project "Taifun"

Impluse (momentum) measured:	2000 kg.sec	therefore, exhaust velocity: c = 1960 m/sec
Weight of Fuel :	10 kg	
Total weight :	20 kg	
Caliber :	10 cm	

Drag coefficient c_w as function of Mach number Ma for angle of attack 0° :

c_w	0.195	0.33	0.52	0.38	0.27	0.225	0.22
Ma	0.5	1.0	1.3	2.0	3.0	4.0	4.5

The variations in air density were considered according to the CINA standard atmosphere. Combustion time varied between 3 and 6 seconds.

The equations of motion were integrated numerically by the iteration method.

Results: Diagram 1 show the relation between flight time and altitude, and between flight time and missile speed, for a vertical launching of a rocket of total weight 20 kg and combustion times 3, 4, and 6 seconds. For a 3-sec combustion period with combustion cutoff occurring at an altitude of 1.66 km, the maximum speed is 1190 m/sec (without the effect of drag it would be 1330m/sec, the loss of speed due to drag during combustion time being 130 m/sec). In this case, the rocket attains an altitude of 7.7 km after a flight of 10 sec, and attains a ceiling altitude of 18.1 km after a flight of 54-sec duration.

If the combustion time is lengthened to 6 seconds, the ceiling altitude is increased by 1 km. (Cf. Diagram 2). Diagram 2 also shows the flight times to target altitudes of 2, 4, 6, 8, and 10 km as functions of combustion time (for rockets of 20 kg total weight, launched vertically). For a flat trajectory, therefore, the combustion time must be as short as possible.

Diagram 3 shows the increase in power output for vertically launched rockets, whose weight has been reduced from 20 to 19 kg, with the amount of

fuel remaining the same as before, viz. 10 kg. The path-time and velocity diagrams of shots fired at angles 45° for a rocket of total weight 20-kg are also shown.

Diagram 4 show the trajectories of a 20-kg rocket (total weight)for a 3-sec conbustion time and elevations of 45° and 80° with the true angles and tangent of initial direction. After a flight of 15 sec the change in trajectory angle for a 80° launching angle will be 3°, and 12° for a 45° launching angle.

The lines of equal flight-time are nearly concentric circles. They can be used to determine the flight time for any range for launching angle between 45 and 90°.

List of illustrations:

Figure 1: Senkrechter Schuss - Vertical launching
Gesamtgewicht - total weight
Tribstoffgewicht - weight of fuel
Impuls - impulse
Geschwindigkeit - velocity
Hohe - altitude
Breandauer - combustion time
Flugzeit - flight time

Figure 2: Steighohe - altitudes of climb
Zielhohe - altitude of target
Laufzeit - flight time

Figure 3: Zielentfernung - distance of target
Erhohung - elevation

Figure 4: Flugbahn fur .... Trajectory for ...
Abschussrichtung - direction of launching
Brennschluss - cumbustion cutoff
Entfernung - distance

Berlin, 28 Oct 1944

Conference of Work Group "Taifun", 17 Oct 1944

Gas generating cartridge: The difficulty lies in the bursting diaphragms which cause discontinuities in pressure. This affects combustion adversely.

"Guanidin" powder is to used for the cartridges. About 200 grams will be required for each cartridge.

Fuze: The AZR 2 fuze will have to modified. The problem of arming it can probably be solved without much trouble.

The missile is to destroy itself after 20 seconds.

Explosive charge: Only 500 grams of explosive can be made available for each missile. This quantity suffices for the destruction of enemy aircraft, but probably not for self-destruction of the missile. In that case, the provision for self-destruction will have to be dropped.

In order to keep open the possibility of later increasing the weight of the charge or of using a larger quantity of lower-grade explosive instead of 500 grams of high-grade explosive, the weight of the explosive used is to be increased to 1000 grams by the addition of fillers.

Launching rack: To be loaded individually with 30 rockets. The mount of the 8.8 cm Flak 37 gun will be used, without barrel, compressed -air counter-recoil mechanism, muzzle brake, and fuze setting machine. The rack, consisting of 30 launcher rails made of angle irons, is to be fastened to the cradle. The launcher rail are 3.5 m long and can easily be exchanged. The launching axes are to be parellel to 2/16°. Since it is expected that there will be sufficient scatter of the rockets to cover the target area, the launchers will not be arranged in divergent directions. The interior diameter of the four anchor points of the guide rails is to be 184 ± 1 mm. The diameter

of the guide bulges on the rocket is 103 ± 0.2 mm.
The alignment of the guide rails is to be checked by means of a sighting test.
The cradle is to be used as quadrant area.
The rear of the launchers is to be fitted with a safety device to prevent the falling out of the rockets when the rack is elevated. The rear and of the rockets and the rear end of the launcher are to be even. The rack is to be loaded manually.

Firing: Electrical. Voltage is supplied by one ground wire and by one wire with a contact on the rack and plugs in the head of the rocket.
Firing is to be carried out by three alternate methods: a) each rocket to be launched individually, b) three successive salvos of 10 rockets each, c) all 30 rockets to be launched in rapid sequence.

Aiming device: Receiver of Data Transmitter model 37 for elevation and azimuth.

Panoramic telescope sight for azimuth setting. Mounted atop the center of the rack.

Berlin, 27 Oct 1944

The "Taifun" project was considered very promising until a few days ago. Its flight time of 14.3 sec for an oblique distance of 10,000 meters is not even approximately attained by any other missile. The shell of the 8.8 cm Flak 41 gun requires approximately 18 seconds to cover this distance.

The investigation and comparison of the ballistic performance of sub-caliber projectiles brought surprising results.

The sabot projectile, fired from the old unmodified 8.8 cm gun, is almost equal in performance to the Taifun. The sabot projectiles fired from the 10.5 cm AA gun or from the 1941 model 8.8 cm AA gun are far superior in performance to the Taifun. If their spin is increased, their performance be improved even more.

The cost of materials for sabot projectiles is low. The saving on steel, explosive and guide ring amounts to 50%.

The Taifun missile, as compared to the sabot projectiles, has the disadvantage of great expenditure of materials and higher scatter.

Its advantage is the simple design of the launching rack which does not suffer from much wear, along with perhaps the ease of manufacture of the missiles.

In respect to accuracy, the Taifun can compete with the sabot projectiles only if ballistic improvements are made. This can be accomplished by proper application of the sub-caliber principle: The head of the Taifun missile is provided with an arrow fin arrangement weighing 5 kg. After combustion cutoff the fins are opened by an explosive cap. The combustion chamber is jettisoned. The performance of this device, as compared to that of the original Taifun missile, is as follows:

Path length	10,000 m	13,000 m
Travel time of arrow projectile	11.5 sec	15.0 sec
Travel time of Taifun	14.3 sec	21.5 sec
Probability of hits of the arrow 1.5 times		2.5 times

The initial velocity of the Taifun would have to be increased in order to decrease the scatter. It may be possible to launch it from a closed tube which contains the launcher rails.

The above considerations, as far as they are concerned with the accuracy of the missile, refer to single shots.

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Berlin, 1 Nov 1944

Conference on Project "Tuifun" on 31 October 1944

A new mount is to be developed by the Skoda works, because the 8.8 cm gun mounts will not be available, since this gun has become more efficient due to the introduction of sabot ammunition.

The rear of the rack is to be painted with luminous paint to facilitate loading.

Electrical equipment: The contact pins on the missile must protrude 4 mm. The pins on the missile are to be solid; those on the rack are to be elastic.

The firing switches used for the two prototype racks are the same as those on the 48 rocket launcher of the Waffen SS. A simplified switch for the production model will be developed.

A device to test the ignition circuits is necessary. Indication devices for the low currents used, however, are hard to obtain. A device which indicates whether or not individual launchers in the rack have misfired would be too costly and will probably not be built.

Current supply: In order to clear up this problem, a decision must be made on battery arrangement and type of fire control unit to be used.

For tactical use a consolidated 12-rack battery is planned. Six of these racks are to fire three salvos of 10 rounds per rack each, to be followed by the firing of the other six racks, while the first six are being reloaded. This means that twelve racks must be aimed and six of then fired simultaneously.

The maximum distance between battery center and director set is to be 300 meters.

The "Malsi" set is to be used as director, connected with a Model 37 data-transmitter. A special safety switch, in addition to the normal "On"

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and "Off" switch is not necessary.

The crew of three is to be housed in a shelter.

Fuzes: The AZR 2 and DWM fuzes available are all pure precussion fuzes. A self-destroying fuze is being developed. An electric fuze, in which a condenser is charged by the exhaust jet of the rocket is planned; it could be adapted to provide for self-destruction.

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Berlin, 27 Nov 1944

Conference of Work Group Taifun, 13 Nov 1944

Salvos and probability of hits: An investigation has shown that salvos against bomber formations must be fired with as little scatter as possible to obtain a favorable figure of rounds fired per hit. The reason probably lies in the fact that the shortened traveling time to the target makes the external ballistic scatter predominate over scatter due to gun director set. The scatter must not be a multiple of that of anti-aircraft guns.

The scatter of individual rockets and their mutual effect must be reduced by all means available. The mutual effect of the "Taifun" missiles will probably be lower than in the case of the "Foehn" missiles, since liquid-fuel rocket gas jets do not diverge much, because of gas expansion, until the gases reach the external pressure.

Salvos are advantageous even if scatter should be greater, since they allow the firing of more rounds within the same short time during which the target can be fired on.

Tests for firing table: The tests are carried out with Navy tracers LH 28, weight 155 grams, length 60 mm, burning time 20 sec. The trajectory is measured in three sections. From 0 to 50 meters measurement is carried out by means of slow-motion movie cameras from the rear and from the side, the sections between 50 and 1500 meters and from 1500 meters to the point of impact are measured by means of phototheodolites.

Director set: The values from the "Malsi" director are transmitted by data-transmitter set 37.

Guiding mechanism: Each missile is launched from two straight angle-iron rails of 3.5 m length. They may deviate from a straight line by 1 mm. Guiding the missile during launching from top and bottom instead of from

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the sides would decrease scatter, but would necessitate higher expenditures for the rack.

The tolerance in direction is 2/16°.

It has been suggested to reduce scatter by firing from rifled launching troughs. Since the jet is undisturbed, inaccuracies in manufacture can probably be compensated for by rotation of the missile around its longitudinal axis. This rotation must occur already at the moment of the missile's leaving the launcher rails. It may amount to 3 to 30 rotations per minute. If the twist of the launcher rail is 180°, the rotations of the missile will be 5 per minute. Due to the effect of the control surfaces, it will be reduced to 4.5 rpm during the combustion period and afterwards will rise to 10 rpm.

Electrical equipment: It has been suggested to use the switch box of the aircraft bomb intervalometer RAB 14 F for checking the firing readiness of the missiles either in salvos or successively. This device would also provide for remote-control firing.

Propulsion of missile: Tests were carried out with nitrogen used as the compressed gas. The thrust is to last for 2.5 seconds and amount to 800 kg. Operational safety has been increased to 95%.

Fuzes: The first 10,000 missiles are to be equipped with the Skoda C-fuze, with pyrotechnical self-destruction by the gas generator cartridge. As a transitional solution, the C-fuze is to be coupled with a powder train fuze for self-destruction.

The final solution is to be in the form of a percussion fuze on the basis of the AZR 2 fuze.

An electrical fuze has been developed. Its advantage lies in the fact that the point of the missile need not be flattened in order to house it. Voltage is generated by a galvanic element whose electrolyte begins operating

only after the breaking of a glass vessel during launching. Self-destruction is accomplished by a simple clockwork mechanism of little accuracy.

Explosive charge: The space in the warhead can accomodate more than 1 kg of explosive. It could hold 1.2 kg. It must still be determined in which location within the warhead this empty space will have the most favorable effect.

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Conference of Work Group Taifun, 1 Dec 1944

State of development: In flight tests, the powder cartridge which was developed pressure-feed the liquid fuel causes diffuculties because of pressure increase due to acceleration.

Alternate materials for the internal tank: An attempt is to be made to substitute glass for the aluminum of which the internal tank is made at present.

Conference on Taifun, Wasserbau-Versuchsanstalt, Munich, 11 Jan 1945

Since launchers can be built with great precision, the guide bulge on the missile will be omitted. The dimensions of the missile are now as follows:

Caliber 101 - 1 mm

Length 1930 mm

Ogive 15 Diam.

Length of control surfaces 320 mm

Width of control surfaces 220 mm.

The plan has been advanced to attach the control surfaces directly to the combustion chamber and nozzle assembly, without the use of a cylindrical part. This would create new aerodynamic conditions which have not yet been determined.

The effect of the jet on the drag coefficient was measured on the A-4 [V-2], and found to increase it by about 50% at Mach number 0.5, and to decrease it by 20% at a Mach number of 3. These results, however, cannot be applied to the "Taifun". Likewise, no information can be given on the effect of the jet on stability.

The dimensions for the Taifun P are: Length 2100 m, caliber 100 mm, ogive 15 diam., length of control surfaces 370 mm, diameter of control surfaces 180 mm, angle of attack 1°. This model has been found to be stable, according to rough calculations

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Conference on "Taifun", 25 Jan 1945

Testing program until conclusion of development stage: Testing of greater nozzle diameter for the attainment of 1500 kg thrust; proper setting of mixing nozzle; contained development of gas generation cartridge; field testing of the above points, of fuzes, and control surfaces; determination of the causes for scatter; ballistic measurement; setting up of firing tables.

Conference on "Taifun" at Bad Sachsa, 2 April 1945

Construction details: At present the Taifun F (liquid fuel) attains a maximum speed of 900 m/sec. The reasons for this low speed are the improperly set mixing nozzles and the tumbling of the missiles, which creates too much drag. Even at the present stage of design, a speed increase to 1200 m/sec could be achieved by lengthening the missile by 30 cm. This would necessitate modification of the launching rack.

The final velocity of the Taifun P (solid fuel) has not yet been measured. Scatter after the end of the combustion period was 1.5 x 2% of the oblique distance to the target.

A standard launching rack for both types of missiles is being made.

Firing is to be carried out in salvos of four shots each, with a 0.2 second interval between salvos. Firing is to be inductive. The period between launching and self-destruction is to be 25 sec with a 4 sec tolerance. A mechanical and an electrical percussion fuze are being tested. The fuze is to respond down to a relative speed of 150 m/sec.

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